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(19) (CA) **CANADIAN PATENT** (12)

(54) Physiological Monitoring System

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ABSTRACT OF THE DISCLOSURE

Physiological monitoring systems for measuring variables such as, for example the temperature or pulse rate in animals usually include a sensor for attachment to the animal, and a telemetry unit for receiving a signal from the sensor indicative of the value being measured. It is necessary to be close to the subject being monitored, and values are obtained on an intermittent basis. By providing a transmitter/receiver, a microcomputer, a source of power and at least one sensor in a remote telemetry unit, and a transmitter/receiver, a source of power and a computer in a master telemetry unit the subject can be continuously monitored, the data being stored in the microcomputer and periodically transmitted to the computer of the master telemetry unit either automatically or in response to a command for such data.

This invention relates to a physiological monitoring system.

Physiological monitoring systems are not new. Examples of such systems are found in Canadian Patents Nos. 738,747, issued to R.J. Preston on July 19, 1966; 801,875, issued to F.R. Anderholm et al on December 17, 1968; 886,724, issued to N. Murata on November 23, 1971; 940,433, issued to C.H. Fuller on December 23, 1975; 1,027,181, issued to R.A. Lewis on February 28, 1978; 1,043,425, issued to D.G. Noiles on November 28, 1978; 1,105,562, issued to P. Schmidt-Andersen on July 21, 1981; 1,128,138, issued to M. Toshimitsu et al on July 20, 1982, and U.S. Patents Nos. 3,212,495, issued to R.J. Preston on October 19, 1965; 4,237,900, issued to J.H. Schulman et al on December 9, 1980; 4,249,538, issued to T. Musha et al on February 10, 1981; 4,321,933, issued to L.R. Baessler on March 30, 1982; 4,456,825, issued to G.J. Veith on November 2, 1982; 4,387,724, issued to D.L. Zartman on June 14, 1983; 4,399,821, issued to D.L. Bowers on August 23, 1983 and 4,531,526, issued to L.J. Genest on July 30, 1985.

In general, physiological monitoring systems have been used for some time to provide management information for animal operations. The principle objective has been to identify the individual animals, and to provide some means for monitoring temperature and heart rate. The systems employ a variety of probes which may be subdermally implanted, located close to the tympanic membrane, or mounted in the vagina for detecting temperature.

Some probes are not internally powered, so that they must be actuated using an external source of power located close to the probe. Such passive probes transmit data only when interrogated. Even in cases where the probe constantly monitors a condition, e.g. using battery operated probes, information is obtained only upon actuating a transmitter/receiver. Thus, information not gathered at the moment of transmission is lost. A problem common to all such devices is that continuous remote monitoring is in general not possible.

The object of the present invention is to overcome the drawbacks of existing apparatuses by providing a relatively simple physiological monitoring system, which is capable of measuring physiological functions such as pulse rate and temperature in a living creature, storing the data, and transmitting the data complete with an identification code via a radio telemetry link.

Accordingly, the present invention relates to a physiological monitoring system comprising remote telemetry means for attachment to the subject to be monitored including sensor means for detecting a condition of the subject, first microcomputer means connected to said sensor means for storing data concerning the sensed condition, and first transmitter/receiver means for transmitting a signal representative of the condition and for receiving command signals; and master telemetry means for communicating with said remote telemetry system including second computer means for storing data and for generating a command

signal, and second transmitter/receiver means for transmitting command signals to said remote telemetry unit, and for receiving data from said first microcomputer.

The invention will now be described in greater detail with reference to the accompanying drawings which illustrate preferred embodiments of the invention, and wherein:

Figure 1 is a schematic block diagram of a remote telemetry unit for use in the system of the present invention;

Figure 2 is a schematic block diagram of a master telemetry unit for use in the system of the present invention; and

Figure 3 is a schematic block diagram of another form of remote telemetry unit for use in the system of the present invention.

With reference to Figs. 1 and 2, the basic elements of the present invention include a remote telemetry unit (Fig. 1) and a master telemetry unit (Fig. 2). The remote telemetry unit is externally or internally attached to the animal to be monitored. The master telemetry unit functions as a base station for collecting and processing data received from one or more remote telemetry units during operation of the latter.

The remote telemetry unit includes a microcomputer 1 for collecting data from one or more sensors 2. The sensors 2 are connected directly to the microcomputer 1. Alternatively, the sensors can be connected to an analog to digital converter 3,

or to a multiplexer 5 which is connected directly to the microcomputer 1 or through an analog to digital converter 6 to the microcomputer 1. The microcomputer 1 is operated by a power supply 7. A transmitter/receiver 8 carrying an antenna 9 is connected to the microcomputer. The transmitter/receiver 8 receives command signals via the antenna 9 from the master telemetry unit, and transmits data from the microcomputer 1 to the master telemetry unit.

Examples of the microcomputer 1 include CPU, RAM's, ROM's and EPROM's, which collect data from the sensors 2, stores the data, performs monitoring routines, and controls transmission of the data to the master telemetry unit. The sensors 2, which are forms of transducers, measure the appropriate physiological function such as pulse rate, temperature and respiration rate, and transmit data to the microcomputer. The power supply 7 is a compact power supply, e.g. a battery, so that the entire remote telemetry unit can be attached internally, subcutaneously or externally to the subject being monitored.

The entire remote telemetry unit is contained in a single package. Very large scale integration (FLSI) is used to make the remote telemetry unit as small as possible, and to keep manufacturing costs as low as possible. The manner of attaching the remote telemetry unit to the subject depends on the use or application. Mounting of the remote telemetry unit subcutaneously possesses the advantage of utilizing the skin

for mechanical protection of the remote telemetry unit. Alternatively, the remote telemetry unit can be injected into the digestive tract of the subject when the physiological functions to be determined require such form of sensing. In cases where relatively short term sensing, or when there is no need for mechanical protection, the remote telemetry unit can be attached to the surface of the skin using an adhesive. For internal or subcutaneous use, the remote telemetry unit can be in the form of a small cylinder (one inch by one-quarter inch). For surface mounting on the skin, the remote telemetry unit can be a thin disc with an adhesive backing. The antenna 9 can be integral with or external to the remote telemetry unit, and in the case of subcutaneous use can extend through the skin of the subject.

With reference to Fig. 2, the master telemetry unit includes a computer 10 connected to a transmitter/receiver 12 on which is mounted an antenna 13. The transmitter/receiver 12 sends command signals to the transmitter/receiver 8 of the remote telemetry unit, and receives stored data from the microcomputer 1 via the transmitter/receiver 8. The usual auxillary equipment, including an LED (light emitting diode) readout device 14, a monitor 15, a printer 16 and a disc storage device 17 are attached to the computer 10.

Referring to Fig. 3, an alternative form of remote telemetry unit includes a computer 40 connected to sensors 42 and 43 (one of each shown). The digital sensors 42 are connected

directly to the computer, while the analog sensors are connected through an analog/digital converter 44 to the computer 40. The microcomputer 40 is connected through a grounded interface 46, a quad line receiver 47, operational amplifiers 48 and 49, a voltage/frequency converter 50, operational amplifier 52, relay 53 and an isolating transformer 54 to the transmit circuit of a communications unit 56. Lines 58 and 59 bypass the amplifiers 48 and 49, the converter 50 and the amplifier 52, connecting the quad line receiver 47 directly to a universal asynchronous receiver/transmitter (UART) 60 and a read only memory (ROM) 61, and connecting the latter to the relay 53. A rate generator 64 is connected to the UART 60.

The computer 40 is also connected through the interface 46, a quad line driver 65, a Schmidt trigger 66, an operational amplifier 68, a frequency voltage converter 69, a Schmidt trigger 70, an operational amplifier 72, a relay 73 and an isolating transformer 74 to the receive circuit of the communications unit 56. As in other embodiments, an antenna 57 is provided on the communications unit 51. A line 77 connects the ROM 61 to the relay 73.

While not illustrated, the master telemetry unit can be identical to the unit shown in Fig. 3, except that the computer 40, sensors 42 and 43, and the analog/digital converter 44 are replaced by a computer with peripheral devices, including a

monitor, printer and data storage.

The quad line receiver 47 is a monolithic quad line receiver designed to interface data terminal equipment with data communications equipment in conformance with the specifications of EIA Standard No. RS-232C (see Motorola Semiconductors Data Sheet). The quad line driver 52 is a monolithic quad line driver also designed to interface data terminal equipment with data communications equipment in conformance with the specifications of EIA Standard No. RS-232C. The voltage/frequency converter 48 accepts a variable analog input signal and generates an output pulse train, the frequency of which is linearly proportional to the input voltage. The same device can be used as a frequency to voltage converter 54, which accepts virtually any input frequency wave form and provides a linearly proportional voltage output (see Teledyne Semiconductor Data Sheet). The inverting Schmidt triggers 66 and 70 are circuits having a high voltage output when the input voltage is low. The output voltage remains high while the input voltage increases until the input voltage exceeds set point. The output voltage then switches to its minimum value and holds that value until the input voltage has decreased below set point.

In operation, the computer of the master telemetry unit identifies a remote telemetry unit to be interrogated, either through its software or by operator request. A digital coded signal is sent via the interface 46 to the quad line receiver

47. The receiver 47 conditions the digital signal to a voltage level acceptable to the digital input voltage signal. The output pulse train is then input to the communications unit 56 via the amplifiers 48 and 49, the voltage/frequency converter 50, the amplifier 52, the relay 53 and the isolating transformer 54. The operational amplifiers 48, 49 and 52, and the voltage/frequency converter 50 are used to condition the signal from the receiver 47 to the transformer 54. The isolating transformer 54 is used to electrically isolate the communications unit from the remainder of the circuit.

The signal from the output of the quad line receiver 47 also goes to the UART 60. The UART 60 receives the serial signal and converts it to a parallel signal which is sent to the ROM 61. The ROM 61 interprets the signal on its address bus (not shown) and if the signal is a command from the computer 40 to transmit, it operates the transmit relay 53 which puts the telemetry unit into the transmit mode of operation. If the transmit signal is not received by the ROM 61, then the ROM operates the receive relay 73 to maintain the master telemetry unit in the receive mode of operation.

The communications unit 56 of the master telemetry unit is normally operated in the receive mode. When the communications unit 56 senses an input to its transmission circuitry, the unit automatically switches to transmit mode and transmits the input data via the antenna 76. When the input data stops, the

communication unit 56 switches back to the receive mode. A suitable communications unit is a Citizen Band transmit/receiver, Julian International Model JWT 603. The unit has voice activated input, and operates at 49.876 megahertz.

When a signal is received by a communications unit of the master telemetry unit via the antenna 76, the signal is directed to the receive port through the isolating transformer 74 to the converter 69. The converter 69 converts the input pulse train to a digital voltage ouput for the quad line driver 65. The driver 65 converts the digital signal to a voltage level in accordance with the standard of the interface 46. The Schmidt triggers 66 and 70, and the amplifiers 68 and 72 are used to condition the signals from the driver 65 to the transformer 74. The signal is then passed to the computer for processing.

As mentioned above, the portion of the remote telemetry unit which sends a signal to the communications unit 56 or receives a signal is the same as the master telemetry unit. The data acquisition portion of the remote telemetry unit functions when the analog sensor 43 sends a signal to the analog-to-digital converter 44. The signal is proportional to the phenomena being sensed, e.g. temperature, pressure, voltage, etc. The analog-to-digital converter 44 changes the input analog signal to a digital signal, which is input to the computer 40 for processing. The digital sensor 42 produces a digital signal, which is sent directly to the computer 40 for processing, and can be used with

the analog sensor 43 to act as a switch indicating that an event has occured.

It will be appreciated that the master telemetry unit is required to communicate with the remote telemetry unit. Consequently the design of the master telemetry unit depends upon whether the unit is portable or stationary, the range required between the two units, the number of remote telemetry units in the system and the type of display required. The transmitter/ receiver operates on the same frequency as the remote telemetry unit. The master telemetry unit antenna would be designed to make up for deficiencies in the remote telemetry unit antenna, e.g. a parabolic antenna could be used to receive a weak signal from a remote telemetry unit and to transmit a strong, omnidirectional signal towards the remote telemetry unit.

The computers are referred to in the generic sense as any of a multitude of commercially available computers having a suitable interface. Communications between the computers and the transmitter/receiver are via the interface. One of the more important features of the invention is the use of a micro-computer as part of the remote telemetry unit for attachment to the subject to be monitored. The microcomputer controls measurement of physiological variables, stores the measurements, identified transmissions from the master telemetry unit, and controls radio transmission of stored data to the master telemetry, unit. There are various advantages to using a microcomputer in

the remote telemetry unit. Data transmission does not have to be continuous, since the data can be collected and stored in the microcomputer for transmission when instructions are received, at predetermined time intervals or if preset values of specific data are exceeded. Because transmission is controlled, power drain on the battery used as the power supply is minimized or conversely, a smaller battery can be used, and one standard frequency can be used when more than one remote telemetry unit is in operation for the same installation. For example, each remote telemetry unit could transmit for approximately two seconds every twenty-four hours and the master telemetry unit would provide continuous twenty-four hour surveillance. There is no danger of losing data, since the microcomputer can have sufficient storage capacity. A microprocessor complete with the components listed hereinbefore can be sufficiently small for subcutaneous implantation in the subject to be monitored. Using very large scale integration technology, it is likely that the battery used for the power supply would constitute the largest component.

Using the communications link between the remote and master telemetry units, it is possible to calibrate the remote telemetry unit for the specific variables being monitored. For example, in order to calibrate the temperature monitoring system, the remote telemetry unit is immersed in a medium such as water prior to attachment to the subject. The water temperature is measured using a thermometer, the temperature is input manually

into the master telemetry unit, which in turn transmits the temperature to the remote telemetry unit. The microprocessor of the remote telemetry unit is programmed to receive the data, compare it to the measurement taken using the temperature tranducer(s), and make the necessary changes to the temperature algorithm used in the microcomputer. Following attachment of the remote telemetry unit to the subject, the temperature, pulse rate, etc. of the subject can be measured using traditional methods, and the data transmitted to the remote telemetry unit. The microprocessor would have the capability of confirming or correcting the algorithm.

When using a microcomputer, each remote telemetry unit can be given a unique digital name or code, which is used when the remote telemetry unit is interrogated, for requesting data transmission from the particular remote telemetry unit or to identify data transmission from a remote telemetry unit.

The system described hereinbefore can be used, inter alia for artificial insemination, live stock performance monitoring, health monitoring and wild animal monitoring. In the livestock industry, data can be collected to determine the estrous cycle in order to increase the probability of successful impregnation. Livestock in test stations and feed lots can be monitored to determine the health, location, feeding habits and weight gain. The monitoring of feeding habits and weight gain would require sensors at feed bunks and load cells to identify the animal. The calving period in commercial cattle operations is

notoriously labour intensive. The system can be used to monitor the cattle, and provide an alarm when physiological changes occur to indicate that the cow is in labour or about to give birth. Branding could be eliminated since each remote telemetry unit has its own unique code used to identify each individual animal.

When used in health monitoring, heart attack or stroke patients can be monitored in intensive care units and/or during recovery. The system allows a doctor to monitor a patient in an environment away from the hospital. If necessary, a pocket carried, rechargeable repeater station can be used to strengthen transmission of the remote telemetry unit signal. By implanting a remote telemetry unit in a bird or wild animal, the need for banding or tagging is eliminated.

THE EMBODIMENTS OF AN INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A physiological monitoring system comprising remote telemetry means for attachment to the subject to be monitored including sensor means for detecting a condition of the subject, first microcomputer means connected to said sensor means for storing data concerning the sensed condition, and first transmitter/receiver means for transmitting a signal representative of the condition and for receiving command signals; and master telemetry means for communicating with said remote telemetry system including second computer means for storing data and for generating a command signal, and second transmitter/receiver means for transmitting command signals to said remote telemetry unit, and for receiving data from said first microcomputer.

2. A monitoring system according to claim 1, wherein said first microcomputer means includes analog/digital converter means, and said sensor means is an analog sensor.

3. A monitoring system according to claim 1, wherein each said remote telemetry means and master telemetry means includes a communications unit containing a transmit circuit and a receive circuit; antenna means connected to said communications unit for transmitting and receiving signals; quad line receiver and voltage/frequency converter means connecting said transmit circuit of the communications unit to said first or second computer means; and frequency/voltage converter means, Schmidt trigger means and quad line driver means connecting said receive circuit to said first or second computer means.

4. A method of calibrating a remote telemetry unit in a physiological monitoring system of the type including remote telemetry means for attachment to the subject to be monitored including sensor means for detecting a condition of the subject, first microcomputer means connected to said sensor means for storing data concerning the sensed condition, and first transmitter/receiver means for transmitting a signal representative of the condition and for receiving command signals; and master telemetry means for communicating with said remote telemetry system including second computer means for storing data and for generating a command signal, and second transmitter/receiver means for transmitting command signals to said remote telemetry unit, and for receiving data from said first microcomputer, said method comprising the steps of accurately determining a value of the condition to be monitored; manually inputing the value into the master telemetry unit so that the value is transmitted to the remote telemetry unit; and programming the remote telemetry unit to receive the value and to compare such value with the values obtained using said sensor means, and to make the changes to the value algorithm in the first microcomputer means necessary to ensure accurate indication of the value by said system.

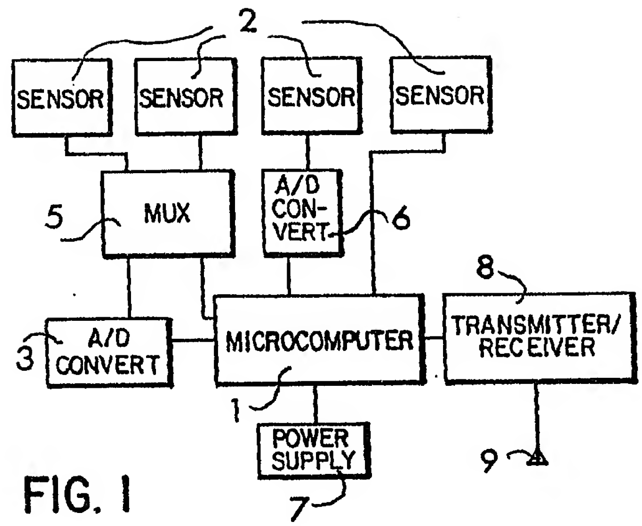
2
SENSOR
SENSOR
SENSOR
SENSOR
5
MUX
A/D CON-VERT
6
8
TRANSMITTER/ RECEIVER
3
A/D CONVERT
MICROCOMPUTER
1
POWER SUPPLY
7
9

FIG. 1

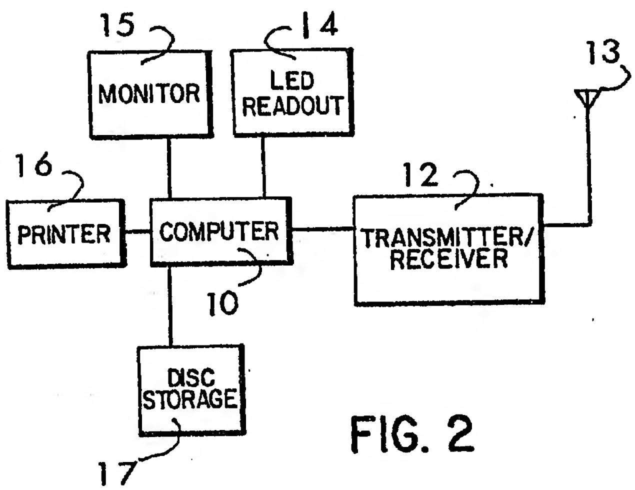
15
MONITOR
14
LED READOUT
13
16
PRINTER
COMPUTER
12
TRANSMITTER/ RECEIVER
10
DISC STORAGE
17

FIG. 2

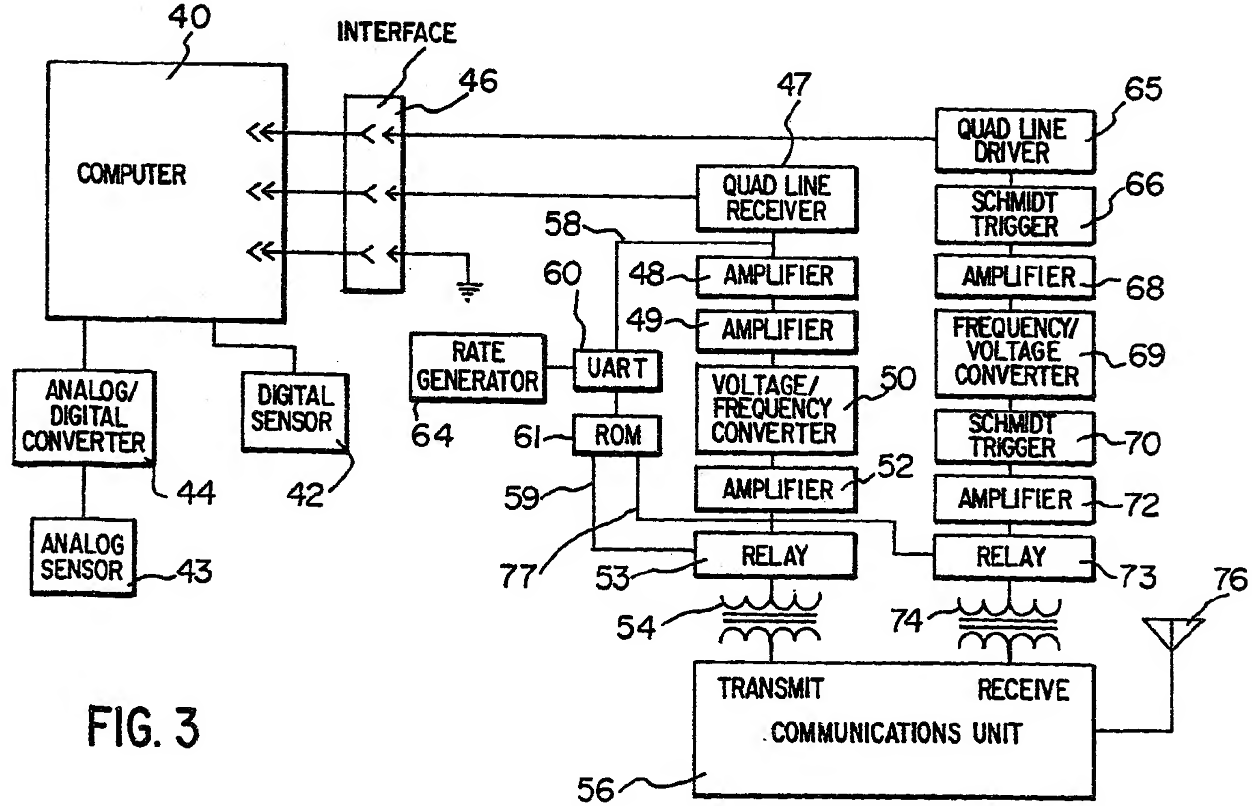

FIG. 3

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